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ABSTRACT

The relevance of psycholinguistic and educational research on passage structure and processing for the design of reading achievement tests is discussed. This research would provide a more objective basis for the writing of passages and items. Two aspects of content validity are distinguished and the relevance of psycholinguistic research to them is examined. The two aspects are the validity accruing from appropriate selection of skills to be tested, and validity based on relevance of items to the selected skills. Key linguistic and psychological terms are defined and several specific reading models are discussed. Their contributions to reading achievement test design are assessed. Analysis of passage structure can be used as an editing procedure to check the coherence of stimulus passages. A brief passage is analyzed to illustrate some practical applications of the theory of text structure and processing. The analysis helps distinguish objectively what is literally present from what must be inferred. Scientific descriptions of the skills and reading materials are needed to assess the use of reading skills. (Author/DWH)

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Text Structure, Processing and the Design of Reading Achievement Tests

by

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AUTHOR'S NOTE

This article was originally written for presentation at the annual meeting of the American Educational Research Association, New York, April, 1982. Special thanks are owed to Dale Carlson of the California Department of Education for his encouragement, and to Professors Edward J. Crothers and Walter Kintsch of the University of Colorado, Boulder, for patiently instructing me in linguistics and cognitive psychology. The views expressed here are not necessarily those of the California Department of Education.

ABSTRACT

This paper discusses the relevance of research on passage structure and processing for the design of reading achievement tests. Two types of test content validity are distinguished and the relevance of psycholinguistic research to them is examined. These two types are the validity accruing from appropriate selection of skills to be tested, and the validity based on relevance of items to the selected skills. Key linguistic and psychological terms are defined and several specific reading models are discussed. Their potential contributions to design of reading achievement tests are assessed. Finally, a brief passage is analyzed, and some practical applications of the theory of text structure and processing are examined.

INTRODUCTION

Sternberg (1981) advocated the application of cognitive and information processing psychology to psychometric testing. Although the vocabulary of cognitive psychology is a novelty in reading achievement testing, it can and should be a useful adjunct. The general aim of this paper is to discuss ways in which psycholinguistic and educational research can be applied to the design of reading achievement tests. A central consideration in test construction is content validity. Typically, one of the main objectives of a reading achievement test is to measure how well a person is able to understand a passage. One challenge in test construction is to operationalize the term 'understand" in the foregoing sentence. The intent here is not to carry out a complete and exhaustive operationalization of this term. This requires taking into account the particular circumstances and goals associated with each test. Rather, the intent here is to stimulate awareness of research that appears particularly promising, to illustrate relevant issues, and to describe a concrete application of the theory to test design.

Frase (1975, p. 4) suggests that what is learned by reading is "the result of an interaction between what the reader

attempts to do and the constraints that the stimulus materials place on those adaptive strategies." This definition focuses attention on the passage itself and on the cognitive processes in comprehension. One limitation of early psycholinguistic research was the lack of a theoretically based yet practical way of describing the meaning of a passage. More recently there has been a trend toward research which is based on explicit theories of passage structure. (Frederiksen, 1975a, 1975b; Meyer, 1973, 1975; Kintsch and van Dijk, 1977; Grimes, 1975; Halliday and Hasan, 1976; van Dijk, 1978; and Crothers, 1979). This research has begun to interest educators. Lucas and McConkie (1980) parsed passages into a propositional network representation in order to identify propositions which are relevant to test items and describe the relationship of the proposition to the item. This is in the tradition of content standard testing discussed by Ebel (1962) and Bormuth (1970). A traditional problem with readability indices has been their lack of sensitivity to passage content. Kintsch (1979) has described a readability formula which takes into account reader inferences and the propositional structure of passages. Crothers (1972), Gentner (1976), Kintsch (1974) and Meyer and McConkie (1973) provide empirical support for a relationship between comprehension and memory and the hierarchical level of information in the passage. Brown, Campione and Day (1981) describe the use of summarization rules as a check for comprehension and retention of information.

These studies support the concept of reading as an interaction between passage structure and cognitive processing. It is worthwhile to consider the implications of this perspective for the design of reading achievement tests. The next section of the paper discusses ways in which theory can be helpful in selection and definition of skills to be assessed by a test.

Content validity. Traditionally, "to demonstrate the content validity of a set of test scores, one must show that the behaviors demonstrated in testing constitute a representative sample of the behaviors to be exhibited in a desired performance domain." (Standards, 1974). Test item specifications are designed to define and describe the skills that the test is intended to assess. In particular, a set of item specifications can be used to examine performance in particular skill areas. On the basis of this examination educational resources can be allocated rationally to areas of need. In order to make these kinds of decisions with confidence the test must possess content validity. Two aspects of content validity can be distinguished here. On the one hand, a definition of the appropriate performance domain can be obtained from textbooks in common use, descriptions of scope and sequence, and other relevant documents. The second aspect of validity requires that the items assessing each selected skill are in fact relevant to that skill. For example, a skill commonly taught is infer-

ring the main idea of a passage. A brief operational definition of this skill area might be the following: given a passage, the student will identify the primary topic of the passage. Suppose a multiple choice item is needed. The task of the item writer is to construct an item requiring the student to pick the theme from several options, one of which expresses the main idea, and the others of which do not. The operational definition contains two problematic terms, "identify" and "primary topic". Identification is a cognitive process which involves inference. "Topic" is a literary-linguistic term which is precisely defineable in the context of a theory of passage structure. Typically, the item writer receives little guidance in defining these terms and must proceed on the basis of intuition. Undeniably, there are various intuitive conceptions of this particular skill, of what constitutes the topic of a passage, and how the topic is inferred. Many of these intuitive conceptions may possess more than a little validity. Yet, when one considers the enormous amount of resources devoted to testing, and the importance of the decisions made on the basis of testing outcomes, it is apparent that more than just intuitive conceptions are needed. Psycholinguistics provides theoretically based and empirically tested procedures for defining such skills.

Definitions. It is useful to define briefly some key terms. The meaning of a passage can be represented in terms

of a network of propositions and connectives. Propositions consist of a predicate, represented in the passage by a verb or an adjective, and one or more arguments. Propositions are underlying units of meaning, and should not be confused with the passage surface structure, even though words from a passage can be used conveniently to represent the elements of a proposition. For instance, a sentence, "John gave Mary a hug" can be represented as a proposition by (GIVE: JOHN MARY HUG). In this case the predicate is "GIVE", and the arguments, presented in order of agent, recipient and object are "JOHN", "MARY", and "HUG". This type of analysis has its roots in Fillmore's (1968) theory of case grammar.

The set of connectives includes conjunctions, such as "and", "or", "if-then", and so on. Other types of connectives are expressions of causality, spatial and temporal contiguity, and reference. Meyer (1975) and Crothers (1979) have noted that connectives help to establish the ordination of propositions. For instance, the connective "OR" can be used to coordinate two or more propositions. By contrast, the connective "WHEN" establishes one proposition as superordinate, and others as subordinate.

Propositions can be explicit or they may be inferred. Inferences are drawn in order to connect otherwise isolated propositions to the passage structure. Authors often assume background knowledge on the part of the reader, and do not

include information that appears redundant, or is commonly presupposed. In order to grasp the author's intent this information must be inferred by the reader.

The microstructure of a passage consists of the relationships between the elements of individual propositions, and of the relationships between propositions (van Dijk, 1977). Text macrostructure refers to the ordination of propositions. Certain propositions are more superordinate than others. The ordination of propositions establishes a hierarchy. The description of the levels of this hierarchy is a description of the passage macrostructure. Superordinate propositions usually occur in a summary or abstract of the passage. Propositions which are subordinate represent passage detail.

Kintsch (1977) has remarked that the reader must be able to integrate the new information presented in a passage with the old information. The coherence of the reader's representation depends on this synthesis of information. Coherence requires the absence of logical contradictions, a consistent causal, spatial and temporal ordering of events and objects, and the consistent use of referring expressions. A requirement for coherence of macrostructure is that the passage have some definite theme or topic.

Conventionally written passages possess a schematic structure or schema. The concept of schema (Minsky, 1975)

refers to a traditional organization of the passage. For instance, many stories are organized into a "setting, complication, resolution and evaluation" pattern. The setting typically describes the physical circumstances of the story and introduces the characters. The complication is generally a problem to be solved. The resolution is the solution of the problem, and the evaluation is the moral or point of the story. Research reports are another type of passage with a well defined schema. These usually contain an abstract, literature review, statement of hypotheses, method section, results and discussion. Fetler (1979) has discussed schemata in question and answer dialogues. Presumably, experienced readers tend to expect schematic organization, and use it to guide their processing of the passage.

Models of reading. What follows is a brief discussion of three contemporary process models of reading. The purpose of this section is to describe concepts of cognitive processing and passage structure. The models of Frase (1975) and Rothkopf (1976) illustrate the range of cognitive processes used in reading. The model of Kintsch and van Dijk (1978) illustrates the use of detailed linguistic descriptions of passage structure. The process model approach clearly distinguishes between the material to be read, the processes of comprehension, and the memorial consequences of the processing.

Frase frames his model in terms of four levels of processing. The results of earlier levels can affect later processing. The reader's activities are goal directed and the performance or goal set can be influenced by explicit learning goals. Level I processing involves establishing the performance set. Encoding of orthographic, syntactic or semantic aspects of the passage is level II processing. Performance set and encoding determine what is available to higher level processes. Rehearsal and integration of encoded information are level III processes. At this stage information may be input to long term memory. Level IV processes, the retrieval and generation of information operate independently of the earlier processes.

Rothkopf distinguishes between nominal stimuli or physical passages, and effective stimuli or usable repesentations of passages reconstructed by the reader. Primary mathemagenic processes take nominal stimuli as input. These processes include eye movements, translation of the input into acoustic-motor format, and syntactic analysis. Secondary mathemagenic processing involves operating on usable representations by collation, integration and elaboration of information. Rehearsal regulates the transfer of usable representations into long term memory. A passage can be processed in different ways depending on task demands. This may involve selective processing of different parts of the passage, and differences in the extent to which certain information is rehearsed or elaborated.

Rothkopf and Frase describe in detail the translation of printed sentences into memory representations. The reading processes in their models are of two kinds. Either they describe the encoding of sentence meaning, or they describe comprehension processes which operate on the encoded meaning. The processing is guided in accordance with the reader's particular goal orientation. As a result it is possible to describe the effects of various learning strategies adopted by the reader and of learning instructions. The processing described by Frase and Rothkopf is linear in the sense that their models operate serially on one sentence at a time. The linear approach can be expanded, however, to take into account the relationships between many different propositions in a passage's structure.

Kintsch and van Dijk assume that the meaning of a passage can be represented in terms of microstructure and macrostructure. Three types of processes are distinguished. First, propositions are organized into a coherent structure. A second set of processes reduces this set of organized information into a summary. Finally, a third set of operations governs recall of stored information. Encoding of propositions is not part of the model, although similar processes are described by Frase and Rothkopf and have been studied by Anderson and Bower (1973) and Kintsch (1974). Propositions are processed in groups of five to nine in the order of their appearance in the passage. The processing of

each group of propositions is called a cycle. During each cycle some of the propositions are stored in short term memory, and are available for connecting with the next set of input propositions. Processing in short term memory involves a finite probability of storage in long term memory.

The model produces a coherent network of propositions. The nodes of the memory network are individual propositions, and the lines are shared references. The organization of the network is determined by the choice of propositions left in short term memory between cycles. There are two strategies for selecting these propositions. First, those propositions should be selected which are important in the sense of being connected to many other propositions. The second principle is that more recently processed propositions are more likely to be selected.

A summary of the passage is obtained from the macrostructure. Propositions that are redundant or irrelevant may be deleted or generalized, and new propositions may be inferred. The deletion, generalization and inference operations are applied in cycles with increasingly strict criteria for relevance. Products are a summary, abstract, theme and main idea.

Applications in test design. How might these theories be useful in the design of reading tests? Applications are

suggested by the distinction of two components of content validity: Certain skills to be assessed must be selected; and there must be assurance that the items in fact assess the selected skills. Assuring that the selected skills are in fact assessed is a matter of careful analysis of the stimulus passages and items. It is in the analysis of passages and items that theories of structure and processing are useful. One advantage of relying on explicit and experimentally tested theory is the possibility of systematic classification of items in terms of skills. Analysis of passage structure involves the development of an extensive typology of types of propositions, connectives, inferences, referential devices and rhetorical constructions. Explicit criteria can be specified for generating summaries, abstracts, themes and topics of passages. Generally, given a network representation of the meaning of a passage, it is possible to locate and describe local or global patterns of organization, to tabulate recurring phenomena, and to describe the component propositions in terms of their relations to other propostions. The various identifiable structures and processes involved in comprehension can be objectively correlated with skills.

Analysis of passage structure can be used as an editing procedure to check the coherence of stimulus passages. Passages which are not well written can be expected to confuse or distract the reader, and introduce "noise" into the meas-

urement process. Examples of phenomena which detract from coherence are literal or inferrable contradictions, the presence of propositions which do not relate to the rest of the passage, ambiguities in spatial, temporal or causal sequence, and references which are not satisfied or are vague. Even careful item writers and proof readers can sometimes overlook these kinds of phenomena. A systematic analysis of the passages is helpful in avoiding such oversights.

How the analysis of a passage might proceed is illustrated here. The passage selected for analysis is a short narrative. The content, length and difficulty are typical of what one might find in a third grade reading achievement test. The body of the passage follows.

> The wind was icy cold, and black clouds were covering the light of the moon. Bob saw a little cave in the rocky mountainside. He climbed between two big rocks. Suddenly he fell, half frozen, to the dry ground inside the cave. He tried to catch his breath. Then he heard it - the slow, deep breathing of a sleeping bear in the corner of the cave.

The first stage of the analysis involves a decomposition of sentences into propositions using methods similar to those of Turner and Greene (1979). The results of this are shown in Table 1. For convenient reference, individual propositions are numbered in the column on the left. On the right, propositions are displayed, enclosed in parentheses. Predicates are written first, followed by a colon. Arguments are separated by commas. Horizontal lines separate groups of propositions corresponding to differrent sentences.

Insert Table 1 about here.

The first six propositions correspond to the first sentence, propositions seven through twelve correspond to the second sentence, and so on. Proposition three illustrates that entire propositions can be embedded as arguments in new propositions. Here the predicate is a conjunction, and the arguments are propositions one and four. Proposition twelve illustrates this in a slightly different way. Bob's climbing action is described in proposition eleven. The location of that action is described in proposition twelve.

Figure 1 displays a network representation of the passage. The numbers correspond to the propositions in Table 1. The lines correspond to connectives between propositions. Not all possible lines are drawn, but only those needed to display the overall structure. For instance,

based on the relationship of identity, it would be possible to connect every proposition containing the element "BOB" with every other proposition containing that element. Although this would produce a more complete analysis, the resulting network would be much less perspicuous, and less useful for applied educational and psychological purposes. The structure of the network is largely determined by the proposition list. For instance, the repeated argument, "COLD", is the basis for connecting propositions 1 and 2. The conjunction in proposition 3 is a branching point for for 1 and 4.

Insert figure 1 about here.

Writing test items. The analysis presented so far is useful for writing and grading certain kinds of test items. For instance, to test the skill of remembering the gist of a passage, a student can be asked to write or select a summary, an abstract, or even just the theme or topic of the passage. An objective way to determine the topic of a passage is to look at argument repetition. This can be done either within each schematic section, or overall. Looking at frequencies overall, "BOB" is repeated explicitly eight times, compared to five times both for "CAVE" and "BREATHING". (The "IT" in 24 counts once for "BREATHING".) If implicit repetitions from embedded propositions are included in the counts, the tally for "BOB" rises to fourteen. Pre-

sumably any description of the topic would take account of these frequently recurring elements. Of course, if the passage included a resolution and evaluation the counts might differ.

An approach which relies more on the meaning of the story is to analyze the network representation. The depth of a proposition is defined as the number of propositions to the left of it in the network. Thus, propositions 3, 7, 11, 15, 21 and 23 have a depth of zero, propositions 1, 4, 9 etc. have a depth of one, and so on. The deeper a proposition is, the more likely it represents detail. The more shallow the proposition, the more likely it represents thematic material. Thus, in the introduction, the most salient point is that Bob saw a cave, (proposition 7). That the cave was little, in a mountainside, and that the mountainside is rocky (propositions 8, 9 and 10) are ancillary facts. A summary of the passage would delete ancillary material, retaining only what is most salient. A good summary of the passage would include that Bob saw a cave, that he climbed and fell into it, and that he heard the breathing of a bear. It would not include the details that the ground of the cave was dry, or that the bear was in a corner.

The analysis helps to distinguish objectively what is literally present in the passage from what must be inferred. The analysis in Table 1 is purposely very literal in that it

only contains what is explicit in the text. However, from the setting one can infer that the time is night, and less trivially that Bob climbed into the cave for shelter from the icy wind, that the two big rocks are by the mouth of the cave, and that Bob had to catch his breath from the exertion of climbing and falling. Once these inferences are brought out, one can much more objectively write items testing for literal and inferential comprehension.

Conclusions. The purpose of this paper has been to discuss ways in which psycholinguistic and educational research on passage structure is be relevant to reading achievement test design. The main argument is that this research can help provide a more objective basis for the writing of passages and items. A concrete example of this, involving the determination of a passage summary and topic was illustrated.

It might be argued that test construction is already quite difficult enough, and should not have to shoulder the additional burdens described here. In reply, the models of Frase, Rothkopf and Kintsch and van Dijk make clear that reading is not a simple process. To assess the use of reading skills, both scientific descriptions of the skills and of the reading materials are needed. Intuitive conceptions of these can serve only up to a point. Scientific conceptions, grounded in empirical research, would be an improvement.

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TABLE 1

Decomposition of Text into Propositions

Proposition number	Proposition
1	(WAS: WIND, COLD)
2	(ICY: COLD)
3	(AND: 1, 4)
4	(COVERED: CLOUDS, LIGHT)
5	(BLACK: CLOUDS)
6	(OF: MOON, LIGHT)
7	(SAW: BOB, CAVE)
8	(LITTLE: CAVE)
9	(IN: MOUNTAINSIDE, CAVE)
10	(ROCKY: MOUNTAINSIDE)
11	(CLIMBED: BOB)
12	(BETWEEN: ROCKS, 11)
13	(TWO: ROCKS)
14	(BIG: ROCKS)
15	(FELL: BOB)
16	(SUDDENLY: 15)
17	(FROZEN: BOB)
18	(TO: GROUND, 15)
19	(DRY: GROUND)
20	(INSIDE: CAVE, 15)
21	(TRIED: BOB, 22)
22	(CATCH: BOB, BREATH)
23	(THEN: 24)
24	(HEAR: BOB, IT)
25	(HEARD: BOB BREATHING)
26	(SLOW: BREATHING)
27	(DEEP: BREATHING)
28	(OF: BEAR, BREATHING)
29	(SLEEPING: BEAR)
30	(IN: CORNER, 29)
31	(OF: CAVE, 30)

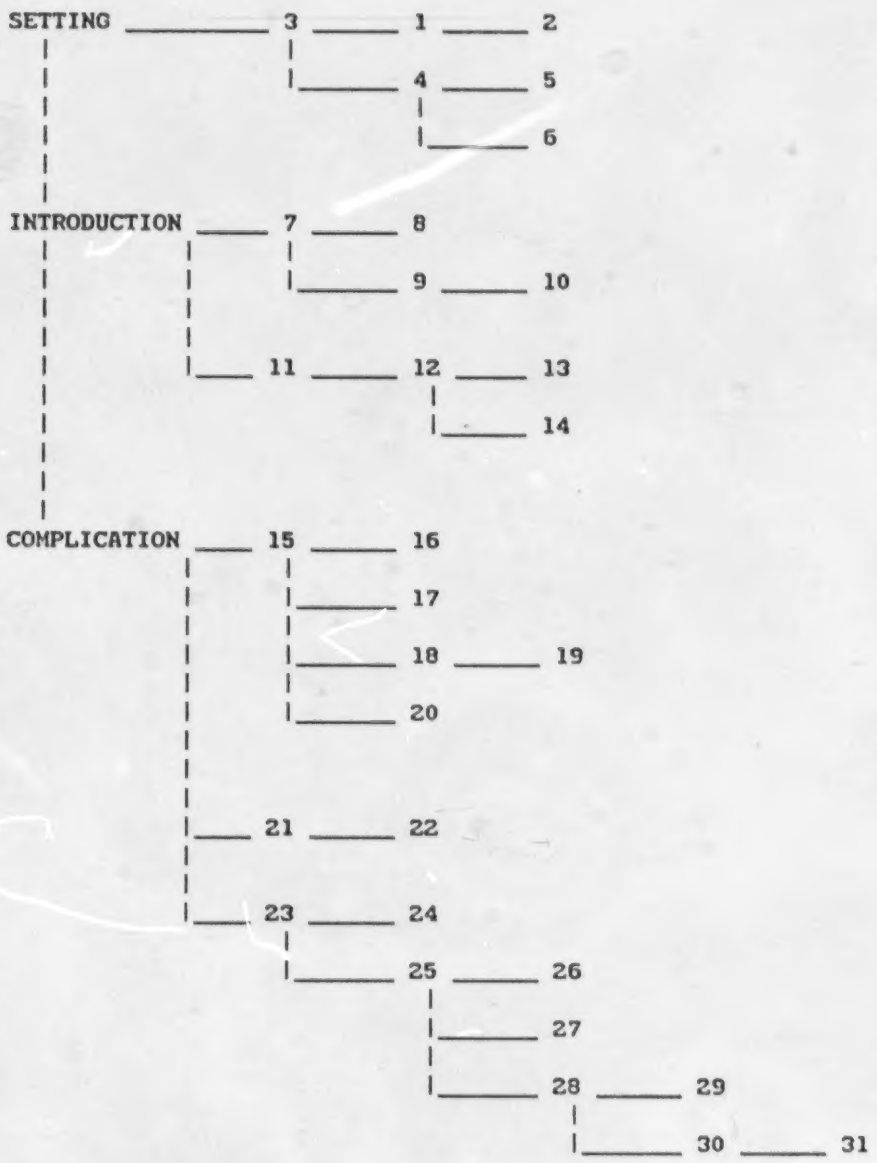

Figure 1: Network representation of the sample text.